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Influence of Environmental Factors on the Growth of the Corn Plant Under Field Conditions

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CONTENTS

SUMMARY

A study, extending over a 4-year period, has been made to determine the effect of environmental factors on the response of corn plants grown under field conditions. The principal factors of the environment which were measured were available soil moisture, air temperature, evaporation and relative humidity. Factors of the environment, during each growing season, were further modified by varying the rate of planting from one to five plants per hill.

Height of plants, increase in leaf area, size of stalks, dry weight of vegetative and reproductive parts, rate of photosynthesis, carbohydrate fractions of leaf samples, and nitrogen content of the ears were measured at regular intervals throughout the growing season. The relation between the plant responses and environmental factors, particularly as modified by rate of planting, was studied.

The rainfall of the growing season, May, June, July and August, is a better criterion for predicting corn yield than the rainfall of the entire year.

Where corn was planted one to five plants per hill there was usually less available soil moisture in the thicker rates of planting than in the thinner rates. The difference was greater in July and August during periods without rain.

During the day relative humidity was 3 to 5 percent lower where plants were planted one plant per hill than where planted five plants per hill. At night the relative humidity was higher in the thinner rates of planting.

The rate of evaporation from porous porcelain atmometer cups in cubic centimeters was 22 percent greater during July and August where there was one plant per hill than where there were five plants.

Height of the corn plants was not appreciably influenced by rate of planting.

There was considerable difference in the leaf area per plant from different rates of planting. In 1932 the maximum leaf area, per plant, was 8,900, 7,908 and 6,573 square centimeters respectively where there were one, three and five plants per hill. Loss of effective leaf area due to firing began earlier and proceeded at a more rapid rate in the thicker rates of planting.

At maturity the average cross-sectional area, at the level of the ground, of stalks, where there were three plants per hill, was 60 percent as large as where there was one plant. Stalks planted, five plants per hill, were only 40 percent as large as where there was one plant.

One hundred hills with one, three and five plants per hill produced a total of 141, 265 and 359 ears, respectively, in 1932. The same year 42 percent of the ears were less than 15 centimeters long—"nubbins"—where there were five plants per hill, while only 12 percent of the ears were "nubbins" where there was one plant per hill.

Rate of planting does not significantly influence the rate of food making per unit of leaf area as determined by increase in dry weight of leaf samples collected at 4:30 a. m. and 4 p. m. Data from these experiments show that rate of food making is proportional to area and not to dry weight of leaf samples.

The quantity of alcohol-soluble carbohydrate fractions separated as diastase extract, dextrins and acid hydrolyzable were determined for leaf samples collected at 4:30 a. m. and 4 p. m. the same day from different rates of planting. There was a statistically significant difference in the non-reducing sugars and diastase extract between samples from different rates of planting and in the reducing and non-reducing sugars, and acid hydrolyzable between samples collected at 4:30 a. m. and 4 p. m.

An analysis of variance showed that there was a significant difference in the quantity of nitrogen in kernel and cob samples attributable to date of collection. There was no significant difference in the quantity of nitrogen in the kernels attributable to rate of planting, while the quantity in the cob samples was slightly significant.

Influence of Environmental Factors on the Growth of the Corn Plant Under Field Conditions[1]

By Harold F. Eisele[2]

Plant growth, measured either as the gradual and continued enlargement of the vegetative parts or as the ultimate production of the reproductive organs, is modified by the environmental factors which surround the plant. In either case the magnitude of the response of the plant and the variation in the environmental factors are more easily determined than is the effect of one or all of these environmental factors on the development of the plant.

To obtain quantitative measures of the influence of environmental factors on the growth of plants, most investigators have studied each factor separately. This is especially true of laboratory and greenhouse experiments where an attempt is made to keep all the factors constant, except one. Few investigators have attempted to study the influence of environmental factors on plants grown under field conditions because of the uncertainty of adequately evaluating the influence of these factors. Recent advances in statistical methods, however, provide means of segregating different factors and of relating a given factor to one or more definite responses of the plant.

Another difficulty encountered in field studies dealing with the effect of environment is that only one crop can be matured each season while the results of several seasons are necessary to obtain measurable variations in factors. In this study it was possible, within a given season, to modify certain of the environmental factors by varying the rate of planting.

A third difficulty arises in that organisms show variation in their rate of growth at different stages of their life cycle. Consideration was given, therefore, to the stage of development of the plant in evaluating the effect of the factors on any particular growth response.

Experiments on which this paper is based have been carried on under field conditions for 4 years. Factors of the environment included in the study are rainfall, available soil moisture,

[1]Taken from a thesis submitted to the faculty of the Graduate College, Iowa State College, in partial fulfillment of the requirements for the degree, doctor of philosophy. Project 89 of the Iowa Agricultural Experiment Station.

[2]The author expresses his deep appreciation to Dr. J. M. Aikman for his assistance and helpful advice in direction of the work and preparation of the manuscript, to Dr. W. E. Loomis for technical assistance in the analysis of plant materials and to Prof. G. W. Snedecor for assistance on certain statistical phases of the bulletin.

temperature, relative humidity and evaporation. Plant responses which are correlated with the environmental factors include rate of growth of the various vegetative parts of the plant, relative rate of photosynthesis, carbohydrate fractions of the leaves, time of development and protein content of the reproductive parts of the plant, and yield of the plants.

HISTORICAL

The influence of rate of planting on the yield of corn has been studied by many workers and is not a major consideration in this problem. Many of the earlier workers failed to realize that there is no one particular rate of planting which is applicable for every region where corn is grown. Hughes et al. (15) have shown that, even within the boundary of a single state, different rates of planting should be used. They recommend three plants per hill spaced 42 inches apart as optimum for southern and central Iowa and four to five plants per hill, of a northern selection, for northern Iowa.

The influence of weather upon the growth of plants is difficult to evaluate. In general the effect of the climatic factor complex, designated as weather, upon crops has been investigated from two angles. The first is a statistical analysis of long-time investigations of rainfall, temperature and yield. The second is an analysis of the effect of certain factors upon the physiological activity of plants during any one growing season. The latter is not well adapted to statistical analysis because of variations in the rate of growth from germination to maturity.

In 1922 Hooker (14) studied the influence of weather on 10 crop plants grown in eastern England from 1885 to 1921 by determining the correlation coefficient between temperature and rainfall and crop yields. It was found, contrary to common belief, that most crops, except potatoes, require cool summers for maximum yields. Fisher (10) obtained similar results when he studied the correlation between rainfall and wheat yields for a 50-year period.

Smith (24) studied the effect of weather upon the yield of corn in Ohio from 1854 to 1913. There was a positive correlation between corn yield and rainfall for June, July and August. For each variation of 1 inch above or below the average rainfall for July, there was a corresponding variation of 2.5 bushels of corn per acre. There was no correlation between temperature and corn yield. This failure may be explained in that the temperature of one section was considered as representative of the whole state.

Vestal and Bell (28), in studying Cercospora leaf spot infection of sugar beet plants, attempted to correlate variations in host infection with variations in environmental factors. Environmental factors were measured by placing recording instruments directly among the plants. There was an appreciable reduction in the relative humidity of the air as well as an increase in air and soil temperature and evaporation in plots where the beets were checked in rows as compared to plots where the beets had been drilled.

Briggs et al. (6), (7) have quite carefully analyzed the data concerning growth in corn collected from the early work of Kreusler. Most of the data were recalculated as increase in dry weight in terms of Unit Leaf Rate—defined as the increase in dry weight per square meter of leaf area per week, taking as the leaf area the average of the areas at the beginning and at the end of the week. It was observed that the Unit Leaf Rate was positively correlated with weekly mean temperature, weekly hours of sunshine, and rainfall of the previous week, but negatively correlated with rainfall of the same week that the measurements were obtained. Records were begun when the plants were 8 weeks old and continued to maturity.

Brenchley (5) found significant correlation coefficients between the mean maximum and the mean minimum temperatures and growth in peas but no correlation between duration of bright sunshine and growth. Gregory (12) found positive partial-correlation coefficients between relative leaf growth rate of barley and average day temperature but significantly negative coefficients between relative leaf growth and average night temperature.

Surprisingly few significant correlation coefficients have been obtained between plant response and environmental factors. This may be explained by the experiments of Pearl and Surface (21) who were among the first to show that the growth of the corn plant is divided into four cycles. The first or root cycle is marked by a rapid increase in the root system, the second by a rapid increase in leaf area, the third by the development of the reproductive organs and the last by the development of the ear and by maturation.

Intensive work on the problem of cyclic development in plants began with the work of Blackman (4) in 1919. He advanced the theory that the accumulative nature of plant growth may be compared to the accumulation of compound interest on a given principal and called it the Compound Interest Law of Plant Growth. The same year Reed and Holland (23) reported on the growth rate in Helianthus. The increase in height of 50 sunflower plants, which were measured at weekly intervals, formed a curve which agreed very closely with the curve calculated from the differential equation for an autocatalytic reaction.

According to Miller (18) corn plants which were 10 weeks old had attained their maximum leaf area. This conforms to the second phase in the growth curve as described by Pearl and

Surface (21). Hershey (13) found that the most rapid rate of elongation in the corn stem does not begin until about 50 to 60 days after planting, which is at the time of maximum leaf area.

Tincker and Jones (26) were not successful in satisfactorily evaluating the influence of climatic factors on the growth of oats. In these experiments plant growth followed the usual autocatalytic reaction curve. The maximum leaf area of the plants was reached about 3 months after sowing, while the maximum dry weight was not reached until 2 months later.

The question of the rate of food making in the leaves of plants has interested physiologists since the experiments of Sachs in 1883. In these experiments the rate of photosynthesis was calculated by determining the increase in weight of half-leaves. In 1909 Thoday (25) showed that the half-leaf method of Sachs was subject to many errors. It was shown that errors attributable to shrinkage averaged from 5 to 8 percent. The error of unlike half-leaves was probably as large or larger than that caused by shrinkage. It was found that if a die-punch of definite area were used, the error from shrinkage was less than 1 percent. Miller (19), using the leaf-punch method, has shown that the average difference between the maximum and minimum water content of corn leaves during the day was about 5.5 percent.

Miller (20) was among the first to observe the daily variation of carbohydrates in the leaves of corn. He determined the carbohydrate fractions by extraction with alcohol. The total sugars began to increase between 4 and 6 a. m. and reached a maximum between 2 and 5 p. m. after which time they gradually decreased until daylight the following morning. The insoluble carbohydrates reached a maximum later in the day and did not begin to decrease until about midnight.

There are few experimental data which show how much the chemical composition of unit samples of plants are modified by cultivation, rate of planting, application of fertilizer and specific environmental factors. Available data seem to indicate that various cultural practices and environmental factors do not materially influence the physiological balance of plants.

One variety of wheat was grown for 4 years by Le Clerc and Yoder (16) in Maryland, Kansas and California on check soil and on soil transferred from each of the other stations. There were slight differences in the protein content of the wheat grown at the three stations, but it is doubtful whether these differences are significant since the variations in protein content of the plants grown at the same location were almost as great as those of the three regions. Tottingham (27) found that corn withstands modification of composition through variation of nutrient treatment and through variation of climatic factors.

EXPERIMENTAL

MATERIALS AND METHODS[3]

An early maturing, open-pollinated selection of a high yielding strain of Reid yellow dent was used in the experiments. The seed was planted as soon after May 1 as possible: May 4, 1929; May 2, 1930; May 7, 1931, and May 13, 1932. Kernels were planted about twice as thick as necessary and when the seedlings were 2 to 3 weeks old they were thinned to exactly one, two, three, four, or five plants per 40-inch hill. These will be referred to as rates of planting, and plots with one plant per hill will be designated as one's, three plants per hill as three's, etc.

In these experiments there were from 3,920 to 19,600 plants per acre, depending upon the rate of planting. The plots were 5 rows wide and at least 30 hills long. Each rate was replicated five times, except in 1932 when there were 13 replications. All growth measurements and calculations of yield were obtained from the middle row. Because of the amount of labor involved most of the work was done with the one's, three's and five's.

The plots made up a part of a field of corn on a farm near Ames and received cultivation similar to that given by the average Iowa farmer. Each season the corn was planted on fall-plowed ground, following oats and first season sweet clover. The soil type was Clarion loam with scattered areas of Webster silt loam.

Moisture content of the soil from depths of 1 to 5 feet, based on dry weight, was determined weekly throughout each growing season. Available soil moisture was computed by means of the hygroscopic coefficient factor method and determined directly by the wilting of plants in pots of soil.

Air temperature, soil temperature and relative humidity were obtained from recording instruments placed in typical situations in the plots. The recordings were later tabulated at 2-hour intervals. During the middle of the growing season seven 2-hour readings were averaged for the day and five for the night for soil and air temperatures and relative humidity. Atmometers equipped with Livingston spherical porous atmometer cups were placed 1 foot high in each of the planting rates, and the water lost by evaporation was determined at frequent intervals. Rainfall records were obtained from the station located at the Agronomy Farm, 5 miles away.

All measurements were obtained each week from at least 25 plants beginning when the plants were about 3 to 4 weeks old and continuing until maturity. These measurements included height, leaf area, basal area of the stalks and dry weight of stalks and ears. Plant height was taken as the distance from

[3]Progress studies have been published by Aikman (1) and Eisele (9).

the ground to the tip of the highest out-stretched leaf. For the determination of leaf area the length and average width of all the leaves on a plant were measured. Previous measurements showed that .75 of the product of the length and width gives a fairly accurate measurement of leaf area. The total leaf surface was obtained by multiplying this figure by two. The greater and lesser diameters of the stalk at the first internode above the soil were measured. The product of the greater radius by the lesser radius by 3.1416 was considered to be the basal area of the stalk.

Stalks, without roots, were weighed and dried at 100° C. to a constant weight. Only a few plants could be collected because of limited facilities for drying. When the plants had reached a considerable size, the stalks were cut into short pieces and then split lengthwise. These pieces were spread out on paper under greenhouse glass. Usually the stalks were sufficiently reduced in bulk in a day to permit complete drying at 100°C. Although data obtained in this manner are subject to errors, they indicate the trend of increase in dry weight.

As soon as ears were formed they were removed at weekly intervals from the plants selected for dry weight samples. The husks were removed and weighed with the leaves and stalks. After the degree of maturity was noted, green weight of the ears was determined. When dry, the kernels and cobs were separated and weighed.

Final harvesting for yield determinations was made after Oct. 15. The corn from the center row of the plots from which no plants had been removed was harvested and weighed, the number of ears was counted and the size of each ear was recorded. After further drying in a rodent-free room the cobs and kernels were separated and weight of each determined. Final yields were calculated to a moisture content of 15 percent.

To obtain some measure of the rate of food making in the leaves of plants from the different rates of planting, definite areas were cut from the leaves with a Ganong leaf punch. Twenty punches, in duplicate, were taken from the leaves in somewhat the manner described by Miller (19). A typical leaf was selected on each plant. Punches were taken from each plant in the hill. Samples were collected at 11 different times from June 17 to Aug. 18 in 1931 and 9 times in 1932 from June 24 to Aug. 24. In 1931 the samples were collected twice daily, at 4:30 a. m., and again at 4 p. m. In 1932 the samples were collected seven times during the day, at 4:30, 7 and 11:30 a. m., 4, 7 and 10 p. m., and again at 4:30 a. m. the following morning. Through each season the time of collection did not vary more than ½ hour from that given above. The punches were brought to the laboratory as quickly as possible and dried at 100° C. to a constant weight. After cooling in a desiccator, the punches were weighed in tared bottles.

Since there was no significant difference in the daily increase in the dry weight of the unit samples from different rates of planting, a large sample of leaf material was collected to ascertain if there were any differences in the carbohydrate fractions of the leaves from the different planting rates. These samples were collected from the one's, three's and five's on Aug. 24, 1932, at 4:30 a. m. and again at 4 p. m. The mid-ribs were removed, and duplicate 100-gram samples were cut as quickly as possible into boiling 95 percent alcohol. The final alcohol concentration was about 80 percent as specified in the Methods of Analysis of the A. O. A. C. (3). Later the alcohol-soluble sugars were extracted 20 times with 80 percent alcohol and made to volume.

The Munson and Walker method was used for the determination of the sugars. The sugars were calculated as dextrose, and were not recalculated to the fraction being determined, since only relative quantitative determinations were desired. Reducing sugars were first determined on aliquot portions of the alcoholic extract. The non-reducing sugars were hydrolyzed with invertase, and the reducing sugars were then subtracted from this value to obtain total non-reducing sugars.

After the alcoholic extractions were completed the residue was dried to a constant weight in a vacuum oven at 65° C. The material was first ground through a 60-mesh sieve in a Wiley burr mill and then for 8 hours in a ball mill. The material from the ball mill was passed through a 200-mesh sieve. The dextrins, diatase fraction and acid-hydrolyzable polysaccharides were determined from 1-gram samples of the residue. The dextrins were removed with 10 percent alcohol. The diastase fraction was hydrolyzed with Takadiastase, and the remaining material was hydrolyzed with 2 percent hydrochloric acid for 2.5 hours under a reflux condensor and determined as acid-hydrolyzable material.

The kernel and cob material which had been collected at weekly intervals was analyzed for total nitrogen less nitrates. The material was ground in a Wiley burr mill through a 60-mesh sieve. The nitrogen fraction was determined on duplicate 1-gram samples by the modified Kjeldahl method as outlined in the Official Methods (3).

SEASONAL VARIATION AND INFLUENCE OF ENVIRONMENTAL FACTORS

In order to facilitate the explanation and understanding of the more or less specific differences in the responses of the corn plants, the first portion of the discussion of the experimental data will be devoted to a general survey of the environmental

TABLE 1. CORN YIELD, IN BUSHELS PER ACRE, SUMMER RAINFALL, AND TOTAL RAINFALL FOR 1929, 1930, 1931 AND 1932.

Year	Number of plants per hill					Summer rainfall Inches	Total rainfall Inches
	1	2	3	4	5		
1929	------	60.3	71.1	------	61.0	14.40	31.12
1930	37.2	47.8	47.3	37.7	36.8	8.31	18.91
1931	31.4	54.8	52.3	44.2	37.2	12.76	37.73
1932	45.5	70.0	72.5	62.0	60.5	21.91	33.54

factors. Yield, in bushels per acre, commonly is the criterion used in comparing particular strains of corn, various changes in cultural practices, and different years. In this first part yield will be taken as the plant response, and plant growth will be divided into separate responses which can be measured.

RAINFALL AND SOIL MOISTURE

The average seasonal rainfall (50 years) for this section of Iowa is about 32 inches, Reed (22). The total rainfall for 1929, 1930, 1931 and 1932 was 31.12, 18.91, 37.73 and 33.54 inches, respectively, indicating considerable fluctuation in yearly precipitation. During the same years corn planted at the rate of three plants per hill yielded 71.1, 47.3, 52.3 and 72.5 bushels per acre. A comparison of yield and rainfall records shows that yield and rainfall are not closely related for this 4-year period. It is possible that the rainfall of the growing season, which includes the months of May, June, July and August, is more closely associated with corn yield. These comparisons are shown in table 1.

Figure 1 shows the weekly distribution of rainfall during the four growing seasons and the amount of available water in the soil in the 1 and 3-foot depths of representative plots with three plants per hill.

There is a close connection between the weekly rainfall of the four seasons and the fluctuations in available soil moisture. The few moisture determinations made in 1929 showed considerable available moisture in the soil at the peak of the growing season. The available soil moisture in 1930 was below 5 percent from July 13 to the end of the growing season in both the 1 and 3-foot depths. Determinations made in the first 6 inches of soil (not included in fig. 1) showed that the water content had dropped below the wilting coefficient for the soil during this critical period.

Moisture available at the beginning of the 1931 season was less than that of the two previous years, especially at the 3-foot depth. This was a result of the limited rainfall during 1930. Timely rains in May and June increased the water content of the soil, as is shown by the seasonal march of soil moisture for 1931. Except for a short period during the middle of July, soil moisture was probably not a limiting factor for the best growth of corn in the thinner rates of planting during 1932. During August the water content in the soil had probably reached the field capacity, since the soil moisture curve maintained a rather uniform level (fig. 1).

In any of the different rates of planting, prior to the middle of June there was no appreciable difference in the water content of the soil at the same depth. From this time until maturity there was, in general, less moisture available as the rate of planting increased. The variation in the moisture available at

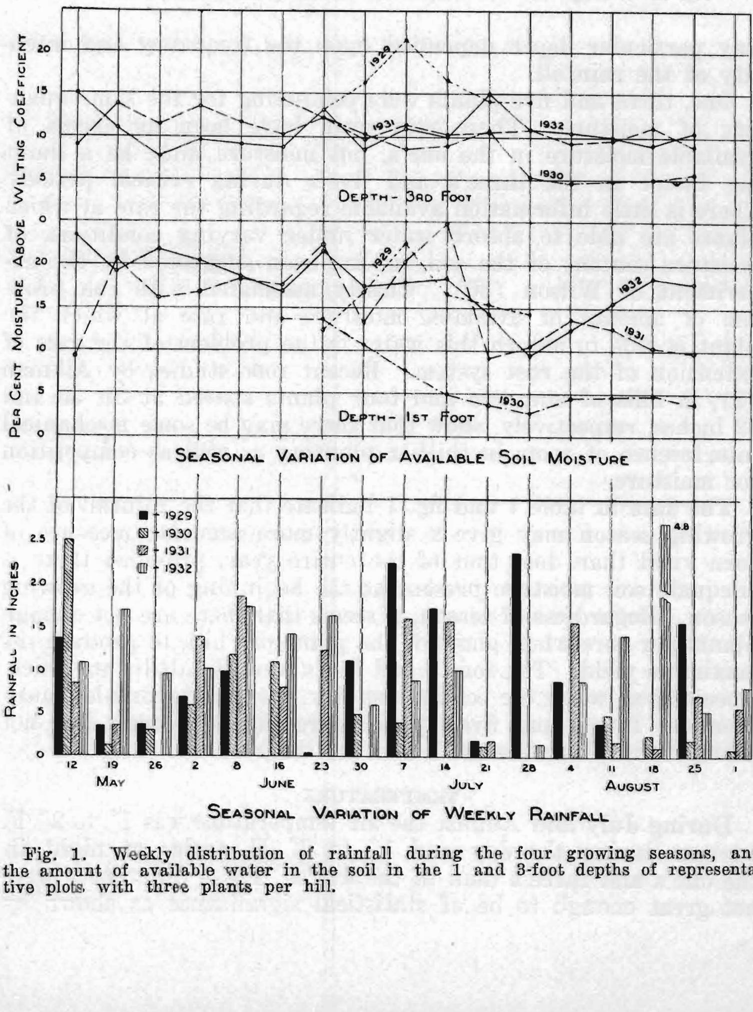

Fig. 1. Weekly distribution of rainfall during the four growing seasons, and the amount of available water in the soil in the 1 and 3-foot depths of representative plots with three plants per hill.

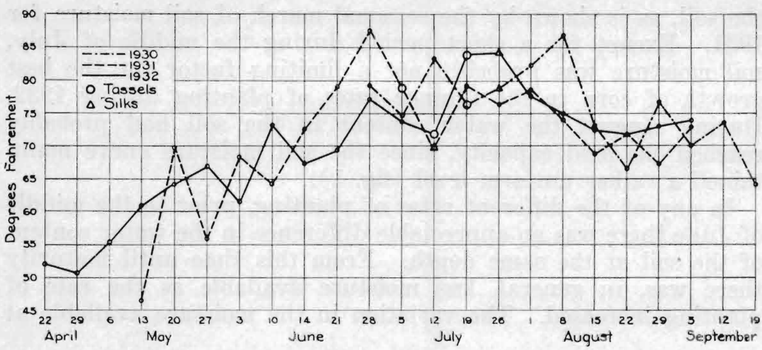

Fig. 2. Average day time temperature for the growing seasons 1930-32.

any particular depth depended upon the frequency and intensity of the rainfall.

One, three and five plants were competing for the same quantity of moisture. There may even have been an excess of available moisture in the one's, but moisture must be a limiting factor in the three's and five's during critical periods. There is little information available regarding the rate at which plants are able to absorb water under varying conditions of moisture content of the soil, as has been suggested by the experiment of Wilson (30). Closely associated with the problem of amount of available moisture and rate at which the plant is able to absorb this water is the problem of the rate of extension of the root system. Recent root studies by Aikman (2), in hills of one, two and four plants spaced at 21, 30 and 42 inches, respectively, show that there may be some mechanical interference of roots in thicker planting as well as competition for moisture.

The data in table 1 and fig. 1 indicate that the rainfall of the growing season may give a slightly more accurate measure of corn yield than does that of the entire year, provided there is adequate soil moisture present at the beginning of the growing season. Regardless of season, it seems that there are not enough plants per acre when planted, one plant per hill, to produce the maximum yield. The four's and five's were decidedly too thick, especially so when the season was dry. Under favorable conditions the four's and five's yield more than the one's but not nearly as much as the two's and the three's.

TEMPERATURE

During July and August the air temperature was 1° to 2° F. warmer during the day and 1° to 2° F. cooler at night in the one's and three's than in the five's. These differences were not great enough to be of statistical significance as shown by preliminary analyses. Figure 2 gives the average day time temperature for the growing seasons of 1930, 1931 and 1932.

The high temperature during June, 1931, was a factor in hastening tassel formation almost 2 weeks. In the 4 years of this study, tassels appeared much earlier than the silks in the thicker rates of planting as compared with the thinner rates. As a result, much of the pollen was shed from the plants in the thicker rates of planting before the silks were formed, and poorly fertilized ears resulted.

EVAPORATION

Evaporation readings were taken at intervals of 3 days or less. The following table gives the total evaporation for the months of July and August. There was no appreciable difference in the evaporation from atmometer cups placed in the different rates of planting during June.

Data show that the evaporation from atmometer cups was almost twice as great in July, 1930, as during the same month of the 2 following years. Because of higher temperature and lower humidity the evaporation stress of the environment is greater during hot, dry seasons than during cooler, more moist seasons. How much these variations actually affect the growth and yield of corn cannot be adequately determined.

TABLE 2. EVAPORATION IN CUBIC CENTIMETERS FROM ATMOMETER CUPS PLACED IN THREE RATES OF PLANTING IN JULY AND AUGUST OF 1930, 1931 AND 1932.

Month	Year	Rate of Planting		
		One's	Three's	Five's
July	1930	1,026	1,061	903
	1931	635	535	472
	1932	668	694	642
August	1930	950	1,068	697
	1931	657	607	536
	1932	324	277	218

RELATIVE HUMIDITY

Relative humidity varied in the different rates of planting. The relative humidity in the one's was 3 to 5 percent lower during the day and as much as 10 percent higher at night than in the five's. Often the air in the five's near the ground would never become saturated at night, while it would be saturated for 1 or 2 hours in the one's. The three's usually held a position somewhat midway between the one's and five's. The differences became less at the top of the plants since wind and sunshine were more equable there. The effect of these fluctuations on the behavior of the plants could not be determined. Reduction

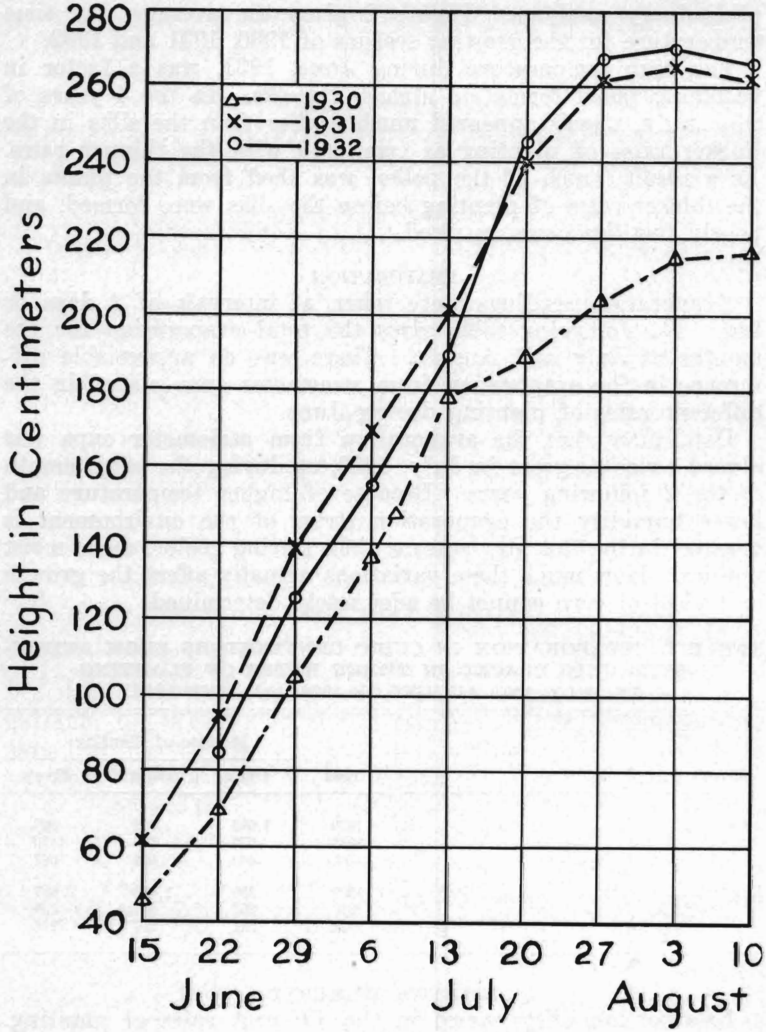

Fig. 3. Average weekly height of plants, three plants per hill, 1930-32.

in relative humidity causes an increase in the transpiration rate from the plants and if of sufficient magnitude would undoubtedly be an important factor where there is a limited supply of water in the soil.

The difference in the average relative humidity between seasons may be much greater than that between rates of planting during the same season. In the dry summer of 1930 the average weekly relative humidity in the five's was about 30 percent less than it was in 1929. Dry growing seasons are usually linked with periods of high temperatures and low relative humidity which result in high rates of evaporation and transpiration.

EFFECT OF MODIFIED ENVIRONMENTAL FACTORS, INDUCED BY VARIOUS RATES OF PLANTING, UPON THE GROWTH OF PLANT PARTS

HEIGHT OF PLANTS

At no time was there a significant difference in height of plants from any rate of planting. During June the plants in the thicker rates were slightly taller than those in the thinner rates. After the first of July the growth in height of plants in the thicker rates was retarded by competition for moisture. By the time the plants had reached maturity those in the thinner rates were slightly taller than those in the thicker rates.

The average weekly height of plants, grown three plants per hill, for 1930, 1931 and 1932, is plotted in fig. 3. There is little difference in the slope of the curve for 1931 and 1932, but height growth was considerably reduced during the dry summer of 1930 as is shown by the gradual flattening of the curve after July 1. The height curve is representative of the typical growth curve found for all annual plants by workers whose results were discussed in the literature review.

INCREASE IN LEAF AREA

A record was made of the number, length and width of leaves on each plant from representative hills in each rate of planting at the time other measurements were taken. Average leaf area from plants in three different rates of planting for 1932 are presented in table 3 and in fig. 4.

TABLE 3. AVERAGE LEAF AREA, IN SQUARE CENTIMETERS, FROM PLANTS IN THREE RATES OF PLANTING. DATA COLLECTED IN 1932.

Date	Rate of planting per hill				
	One	Three		Five	
	Leaf area	Leaf area		Leaf area	
	Per plant and hill	Per plant	Per hill	Per plant	Per hill
June 21	1,061	1,042	3,126	1,004	5,022
June 28	4,334	2,848	8,545	2,198	10,989
July 5	4,769	3,684	11,052	3,277	16,386
July 12	7,101	6,102	18,206	4,572	22,860
July 19	7,396	5,964	17,892	5,628	28,140
July 25	7,199	6,863	20,588	6,573	32,865
Aug. 1	8,639	7,152	21,456	6,010	30,050
Aug. 8	8,740	7,908	23,724	5,910	29,450
Aug. 15	8,900	6,880	20,640	5,333	26,665
Aug. 22	8,240	6,689	20,067	5,026	25,130
Aug. 29	6,683	5,518	16,554	4,447	22,235

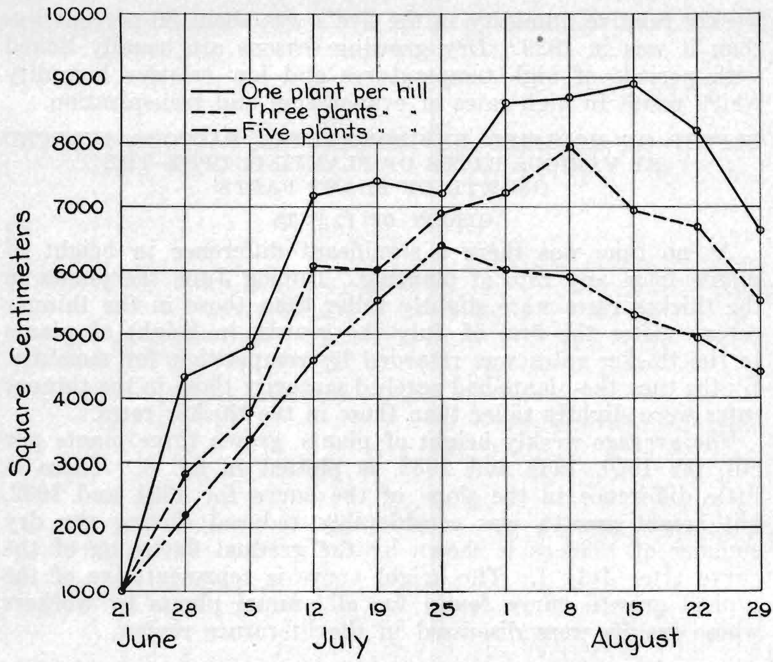

Fig. 4. Average leaf area from plants in three different rates of planting, 1932.

Prior to June 21 there was no appreciable difference in the leaf area per plant regardless of rate of planting. On July 5 there was 32 percent less leaf area per plant in the five's than in the one's and 24 percent less in the three's than in the one's. The maximum leaf area in the five's was reached on July 25; in the three's on Aug. 8; and in the one's on Aug. 15. After July 25 the firing of the lower leaves in the five's was more rapid than was the formation of new leaf area. Leaves in the five's began to die early, indicating that the water supply was inadequate.

Data show that the leaf area in the five's began to decrease shortly after the ears were formed, but the leaf area in the three's and in the one's continued to increase for 2 and 3 weeks, respectively. This rapid decrease in functional leaf area in the thicker rates of planting reduces the available food for the newly formed ears.

During 1930 and 1931 the relative rates of increase and decrease in leaf area were much the same as in 1932. In 1930 July and August were very dry, and the leaf area reached the maximum about July 12 in the five's and 1 to 2 weeks later in the three's and one's. The maximum leaf area was somewhat less in 1930 than in 1932, and the rate of decrease was much more rapid, there being only a few functional leaves remaining by Sept. 1.

SIZE OF STALKS

One of the outstanding differences in the development of the plants in the different rates of planting was size of the stalk near the base. As early as the middle of June, when the plants were about 1 month old, the cross-sectioned area of the stalk in the five's was only half as great as that in the one's. At this time there was no difference in leaf area or in height. At maturity the stalks of the five's were only about one-third as large as those of the one's.

It is rather difficult to explain why the stalks should be so much smaller in the thicker plantings so early in the season when there is no appreciable difference in leaf area. This may be explained theoretically on the basis of the usual growth-differentiation balance in plants. Proteins are necessary for the formation of new cells; water is essential for elongation; and, finally, carbohydrates are necessary for rapid differentiation. Since there is no difference in the total leaf area per plant, there may be a shortage of nitrogen or of available water or both.

There was a wide variation in the formation of prop or brace roots on plants from the different rates of planting. Prop roots began to develop shortly after the formation of the ears about the first of August. On Aug. 10, 1932, notes were taken on the number of prop roots coming from the stalks in each rate of planting. In the one's there was an average of 16 prop roots coming from the first node above the soil level, 8 from the second node and 3 from the third node. In the three's there were nine roots coming from the first node, three from the second and none from the third node. In the five's there was an average of only five prop roots coming from the first

TABLE 4. BASAL AREA PER STALK IN SQUARE CENTIMETERS, OF PLANTS FROM THREE RATES OF PLANTING. AREA IS PRODUCT OF SMALLER RADIUS X LARGER RADIUS X 3.1416.

Date	1931			1932		
	Rate of planting			Rate of planting		
	1	3	5	1	3	5
June 15	0.85	0.66	0.41			
June 22	3.68	1.54	1.16	3.08	2.36	1.95
June 29	8.14	3.99	2.80	7.82	4.49	3.42
July 6	8.48	4.40	3.27	9.49	6.09	4.12
July 13	8.23	4.21	3.14	9.30	5.50	3.77
July 20	7.98	4.30	2.95	8.70	5.50	3.77

node and none from the other two nodes. The same factors which limited the diameter growth of the stalks in the three's and five's as compared with the one's may have limited the normal development of the prop roots.

DRY WEIGHT OF PLANTS

Dry weight of plants from average hills grown at three rates of planting is shown in table 5. There was a gradual increase in the dry weight of the stalks throughout the growing season. Weights of the plants were very similar for both 1931 and 1932 from June 15 to July 5. After July 5, 1931, the weekly increase in dry weight of the stalks was much less than for the same period in 1932. On Aug. 1 the plants weighed about 60 percent as much in 1931 as they weighed in 1932. At maturity the total weight of five plants per hill was about the same as that of three plants per hill. At maturity each plant in the three's weighed only about 60 percent, and each plant in the five's weighed only about 35 percent as much as those planted one per hill.

An examination of curves in fig. 5 shows that the rate of increase in dry weight was greater in 1932 than in 1931. The plants in the one's increase in weight at a rapid rate, while those from the five's increase at a much slower rate. This seems to indicate that each plant in the five's is under competition all through the season, and at no time does there seem to be an excess of "factors" which permit that period of rapid growth typical of biological organisms.

DRY WEIGHT OF EARS

Beginning shortly after the time of fertilization and continuing until harvest the green and dry weights of the ears were obtained. Ears collected on Aug. 1 contained about 80

TABLE 5. DRY WEIGHT OF ALL THE PLANTS FROM AVERAGE HILLS (LESS EARS AND ROOTS).

	Rate of planting					
	1		3		5	
	1931	1932	1931	1932	1931	1932
	gms.	gms.	gms.	gms.	gms.	gms.
June 15	4.8		8.3		10.1	
June 22	18.8	9.7	20.1	31.2	37.9	45.8
June 28	43.0	37.0	91.6	120.6	138.9	122.0
July 5	110.5	101.7	203.6	210.6	214.8	237.5
July 12	183.0	210.0	236.7	486.0	249.0	370.0
July 19	188.6	270.0	367.8	468.0	415.0	545.0
July 25	257.7	399.0	526.1	870.0	452.9	895.0
Aug. 1	258.7	535.0	602.2	909.0	509.2	670.0
Aug. 8		563.0		1,098.0		900.0
Aug. 15		728.0		894.0		1,110.0
Aug. 22		618.0		1,050.0		1,095.0
Aug. 29		762.0		1,383.0		1,335.0

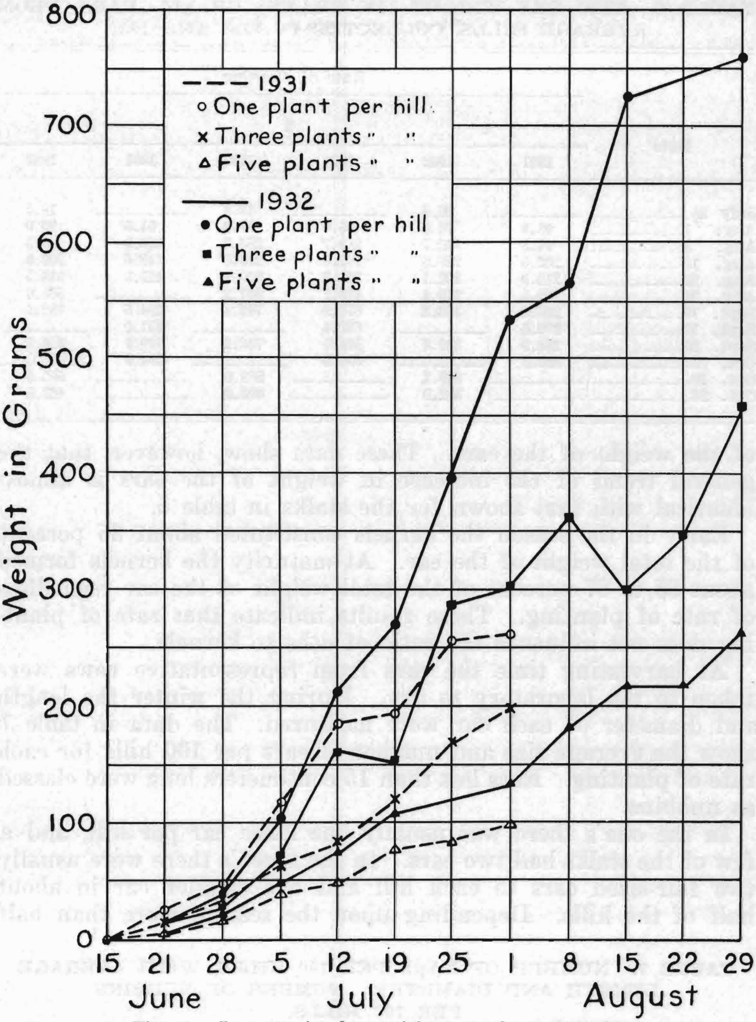

Fig. 5. Increase in dry weight per plant, 1931-32.

percent moisture. The moisture content gradually decreased as the corn became more mature. Early in the season the ears from the five's contained more moisture than those from the thinner rates, but the ears from the five's lost moisture at a greater rate and reached maturity at an earlier date.

The average dry weight for the ears from typical hills is shown in table 6. Because of limited drying space not enough samples were collected every week to give an accurate picture

TABLE 6. THE DRY WEIGHT (IN GRAMS) OF ALL EARS, FROM AVERAGE HILLS, COLLECTED IN 1931 AND 1932.

Date	Rate of planting					
	1		3		5	
	1931	1932	1931	1932	1931	1932
July 25	----------	26.4	----------	43.8	----------	18.0
Aug. 1	63.3	74.6	95.0	97.2	51.5	20.0
Aug. 8	94.8	102.7	239.7	255.3	116.0	96.5
Aug. 15	202.5	226.8	192.6	276.6	342.5	203.0
Aug. 22	210.9	202.1	356.7	369.9	429.3	318.5
Aug. 29	229.1	279.4	439.2	607.2	----------	561.0
Sept. 12	267.0	306.2	670.8	743.4	384.5	752.5
Sept. 19	270.6	----------	602.4	----------	451.0	----------
Sept. 26	288.9	302.6	544.5	762.6	749.5	626.5
Oct. 3	323.5	----------	594.9	----------	584.0	----------
Oct. 10	----------	325.1	----------	588.6	----------	552.5
Oct. 23	----------	382.0	----------	603.3	----------	467.5

of the weight of the ears. These data show, however, that the general trend of the increase in weight of the ears is almost identical with that shown for the stalks in table 5.

Early in the season the kernels constituted about 35 percent of the total weight of the ear. At maturity the kernels formed about 85 to 87 percent of the total weight of the ear regardless of rate of planting. These results indicate that rate of planting does not influence the ratio of cobs to kernels.

At harvesting time the ears from representative rows were taken to the laboratory to dry. During the winter the length and diameter of each ear were measured. The data in table 7 show the average size and number of ears per 100 hills for each rate of planting. Ears less than 15 centimeters long were classed as nubbins.

In the one's there was usually one large ear per hill, and a few of the stalks had two ears. In the three's there were usually two fair-sized ears to each hill and one smaller ear in about half of the hills. Depending upon the season, more than half

TABLE 7. NUMBER OF EARS PER 100 HILLS, WITH AVERAGE LENGTH AND DIAMETER. NUMBER OF NUBBINS PER 100 HILLS.

Rate	Year	Total number of ears per 100 hills	Average length in centimeters	Average diameter in centimeters	Number of nubbins per 100 hills
One's	1931	120	20.1	4.95	19
	1932	141	20.8	4.98	17
Three's	1931	263	17.7	4.45	49
	1932	265	18.9	4.85	23
Five's	1931	326	14.8	4.05	244
	1932	359	14.9	4.42	152

of the ears in the five's *may* be nubbins, and less than four out of the five stalks per hill *may* have an ear.

RATE OF PHOTOSYNTHESIS

In 1931 leaf samples were collected twice daily, 4:30 a. m. and 4 p. m. In 1932 samples were collected seven times from 4:30 a. m. one day to 4:30 a. m. the following day. There was considerable variation among the samples collected in 1932. As a result the data from both seasons were tabulated as increase in unit leaf area from 4:30 a. m. to 4 p. m. of the same day and are shown in table 8. Data show that the dry weight of 20 square centimeters of leaf area was greater in the one's than in the three's and five's, and greater in the three's than in the five's. The dry weight of 20 square centimeters of leaf area increased as the plants became more mature.

On June 17, 1931, 20 square centimeters of leaf area from the plants in the one's weighed about 20 percent more than did

TABLE 8. DRY WEIGHT OF 20 SQUARE CENTIMETERS OF LEAF AREA AT 4:30 A. M. AND THE INCREASE IN DRY WEIGHT OF SIMILAR SAMPLES COLLECTED AT 4 P. M.

Date		One plant per hill		Three plants per hill		Five plants per hill	
		1931	1932	1931	1932	1931	1932
		gms.	gms.	gms.	gms.	gms.	gms.
6-17	Dry wt.	0.0569	----------	0.0521	----------	0.0477	----------
	Increase	0.0212	----------	0.0200	----------	0.0195	----------
6-24	Dry wt.	0.0727	0.0769	0.0618	0.0696	0.0553	0.0693
	Increase	0.0181	0.0172	0.0177	0.0151	0.0156	0.0148
7- 1	Dry wt.	0.0863	0.0877	0.0727	0.0776	0.0657	0.0743
	Increase	0.0083	0.0175	----------	0.0151	----------	0.0134
7- 7-31; 7- 8-32	Dry wt.	0.0929	0.0877	0.0777	0.0757	0.0744	0.0731
	Increase	0.0165	0.0206	0.0160	0.0232	0.0095	0.0231
7-11	Dry wt.	0.1027	----------	0.0862	----------	0.0763	----------
	Increase	−0.0059	----------	−0.0021	----------	0.0008	----------
7-14	Dry wt.	0.1029	0.0975	0.0828	0.0875	0.0742	0.0826
	Increase	0.0109	0.0149	0.0110	0.0139	0.0094	0.0129
7-22-31 7-21-32	Dry wt.	0.1054	0.1030	0.0924	0.0966	0.0788	0.0841
	Increase	0.0134	0.0124	0.0127	0.0066	0.0081	0.0108
7-29-31 7-28-32	Dry wt.	0.1141	0.1028	0.0969	0.0929	0.0886	0.0839
	Increase	0.0077	0.0166	0.0081	0.0120	0.0075	0.0099
8- 5-31 8- 4-32	Dry wt.	0.1149	0.1138	0.0981	0.0987	0.0937	0.0897
	Increase	0.0138	0.0119	0.0128	0.0093	0.0062	0.0101
8-12	Dry wt.	0.1226	----------	0.0979	----------	0.0971	----------
	Increase	0.0126	----------	0.0186	----------	0.0160	----------
8-18-31 8-16-32	Dry wt.	0.1140	0.1140	0.0973	0.1024	0.0843	0.0891
	Increase	0.0055	0.0165	0.0096	0.0050	0.0089	0.0108
8-24	Dry wt.	----------	0.1219	----------	0.1088	----------	0.0995
	Increase	----------	0.0072	----------	0.0075	----------	0.0060

TABLE 9. ANALYSIS OF VARIANCE OF THE DRY WEIGHT OF THE LEAF SAMPLES COLLECTED AT 4:30 A. M.

Source of variation	Degrees of freedom	Mean square
	1931	
Total	32	
Dates	10	85,323**
Rates	2	147,348**
Experimental error	20	1,406
	1932	
Total	26	
Dates	8	46,131**
Rates	2	71,941**
Experimental error	16	999

**Indicates probability less than 1 percent highly significant.

the same area from leaves of the five's. On Aug. 18, 20 square centimeters of leaf area from the one's weighed 11 percent more than the same area from the three's and 28 percent more than an equal area from the five's. From June 17 to Aug. 18, the weight of 20 square centimeters of leaf area increased 100 percent in the one's, 87 percent in the three's and 77 percent in the five's. Similar results were noted for 1932.

There is considerable variation both in the original weight of the leaf samples and in the actual increase in dry weight from each rate of planting for the same day and for different days throughout the season. Some preliminary analyses to determine whether any of these differences were of statistical significance were attempted. The data were analyzed for variance as outlined by Fisher (11).

The first analysis was to ascertain whether or not homogeneous population was being investigated. Table 9 presents the analysis of the variance of the dry weights of the samples collected at 4:30 a. m. The table shows that for both 1931 and 1932 the differences between the mean dry weight of the leaf punches from the different rates are highly significant, as well as those between the means of the dry weights of the leaf punches from the different dates of collection. This indicates that, as far as original dry weight is concerned, three different populations (one's, three's and five's) are being investigated.

The variance between the actual increase in dry weight and the percentage increase in dry weight of the samples collected at different dates and from different rates of planting was analyzed. Table 10 presents only the statements about significance.

As would be expected the differences from date to date are significant. There is some indication that rate of planting did affect the increase in dry weight of a unit area of leaf surface from 4:30 a. m. to 4 p. m. in 1931 but not in 1932. It can probably be assumed that the plants in the five's and probably the three's were too thick for normal development in 1931 when conditions for growth were less favorable than in 1932.

To segregate some of the factors causing the significant difference in increase in dry weight due to date of collection of the samples, the correlation coefficients between increase in dry weight and various environmental factors were determined as described by Wallace and Snedecor (29). The correlation coefficient between the increase in the dry weight and summation of the temperatures above 40° F. for every 2 hours from 4 a. m. to 4 p. m. for the days of collection was determined and was found not to be significant. There was also no significant correlation between the hours of sunshine and the increase in dry weight. Likewise there was no correlation between the maximum temperature and increase in dry weight.

It is entirely possible that if some measure of the intensity of radiant energy could be determined, continuously or in terms of units of heat, there might be a significant correlation between this value and the increase in dry weight. Doubtless other factors such as soil moisture, age of the plants and transpiration rate influenced the differences attributable to date of sampling.

THE CARBOHYDRATE FRACTIONS OF LEAF SAMPLES

The alcohol-soluble carbohydrate fractions were determined in duplicate from aliquot samples. In determining the non-alcohol-soluble fractions duplicate 1-gram samples were used. Potassium permanganate was used for titration, and the limit of errors between duplicate field samples was .3 ml. of .1 N potassium permanganate.

The dry weight of 20 leaf punches from the one's was more than that of the same number of punches from leaves of the three's and five's. Hence, there would be a greater leaf area in 100 grams of leaf material in the five's than in the one's or three's. The dry weight of the alcoholic extraction residue was determined. Since the dry weight of 20 square centimeters of

TABLE 10. STATEMENTS ABOUT SIGNIFICANCE OF CHANGES AND PERCENTAGE CHANGES IN DRY WEIGHT OF LEAF PUNCHES FROM 4 A. M. TO 4 P. M.

Changes in dry weight	Between means of dates 1931	Between means of dates 1932	Between means of rates 1931	Between means of rates 1932
Actual	Highly significant	Highly significant	Significant	Not significant
Percentage	Highly significant	Highly significant	Not significant	Not significant

TABLE 11. MILLIGRAMS OF REDUCING SUGARS FROM LEAF SAMPLES FROM DIFFERENT RATES OF PLANTING COLLECTED TWICE ON AUG. 24, 1932.

Hour of collection	Rate of planting			Between means of rates	Between means of hours
	1	3	5		
4:30 a. m.	290.3	306.3	333.3	Not significant	Highly significant
4 p. m.	464.8	414.2	463.3		

leaf area was known, it was possible to calculate the leaf area in the original green leaf samples.

It was found that 100 grams of green leaf material contained from 3,500 to 4,000 square centimeters of leaf area on Aug. 24. Each determination of the alcohol-soluble fractions was then multiplied by an appropriate factor to make it equivalent to that theoretically obtained from 4,000 square centimeters of leaf area. The statistical determinations of the variation of the non-alcohol-soluble fractions were made on the values found for 1 gram of the residue corrected for area. It was found that the increase in reducing sugars produced by all the plants from 4 a. m. to 4 p. m. was significant. The variation in reducing sugars, attributable to rate of planting, was not significant.

There was a highly significant difference in the quantity of non-reducing sugars found in leaf samples collected at 4:30 a. m. and 4 p. m. There was also a highly significant difference in the quantity of non-reducing sugars in the leaf samples from different rates of planting. The quantity of non-reducing sugars in the leaves decreased with increased rate of planting, being greatest in the one's as is shown in table 12. In the morning there was 35 percent more non-reducing sugars in the one's than in the five's and 67 percent more in the evening. During the day there was almost twice as great an increase in the amount of non-reducing sugars in the one's as in the five's.

The increase in the quantity of non-reducing sugars in the leaves during the day is much the same as that found by other workers. Davis, Daish and Sawyer (8) found that saccharose was much more abundant than reducing sugars in the leaves of mangold. The reverse was true in the petioles and stems.

TABLE 12. MILLIGRAMS OF NON-REDUCING SUGARS FROM LEAF SAMPLES FROM DIFFERENT RATES OF PLANTING COLLECTED TWICE DURING THE DAY.

Hour of collection	Rate of planting			Between means of rates	Between means of hours
	1	3	5		
4:30 a. m.	859.2	749.1	637.0	Highly significant	Highly significant
4 p. m.	2,027.3	1,641.4	1,291.4		

They explained the predominance of saccharose in the leaves on the basis that saccharose was the first product of photosynthesis.

An explanation of the significant difference in the amount of non-reducing sugars produced by plants from the three rates of planting from 4:30 a. m. to 4 p. m. seems impossible at this time.

Neither time of collection nor rate of planting seemed to affect the fraction of the residue extracted with 10 percent alcohol and designated as dextrins. In all the determinations the dextrin content varied between 25 and 30 milligrams per gram of residue or about 500 milligrams per 4,000 square centimeters of leaf area from both morning and evening samples and from samples from different rates of planting.

After the dextrins had been removed with 10 percent alcohol, Takadiastase was added to the remainder of the residue. The portion which was hydrolyzed by the Takadiastase was designated as diastase extract. Table 13 shows amounts of diastase extract in the different samples, together with the results of the analysis of variance. There was a significant difference in the amount of diastase extract in the samples which could be attributed to rate of planting, but the difference due to time of collection was not significant. Since the leaves of the one's are thicker than those of the three's and five's, the larger diastase content in the one's may be the result of the increased development of leaf tissue.

TABLE 13. MILLIGRAMS OF DIASTASE EXTRACT FROM 1 GRAM OF RESIDUE CORRECTED FOR LEAF AREA.

Hour of collection	Rate of planting			Between means of rates	Between means of hours
	1	3	5		
4:30 a. m.	64.34	59.02	54.78	Significant	Not significant
4 p. m.	68.73	56.79	56.82		

Determinations showed that the acid hydrolyzable content of the leaf tissues was much larger than any of the other carbohydrate fractions. It was three to four times as large as the non-reducing sugars and diastase extract fractions. Data in table 14 show that there was no significant difference in this fraction which can be attributed to rate of planting but that there was a significant difference in the samples collected at different hours during the day. There was slightly more of this material in the leaves from the thicker rates of planting, than in the leaves of plants from the thinner rates of planting, which is the reverse of what was found for the non-reducing sugars and diastase extract.

TABLE 14. MILLIGRAMS OF ACID HYDROLYZABLE MATERIAL FROM 1 GRAM OF RESIDUE CORRECTED FOR LEAF AREA.

Hour of collection	Rate of planting 1	3	5	Between means of rates	Between means of hours
4:30 a. m.	184.1	208.2	221.5	Not	
4 p. m.	221.2	225.7	228.7	significant	Significant

WEEKLY VARIATIONS IN THE NITROGEN CONTENT OF EARS

As soon as it was possible to separate kernels and cobs, nitrogen determinations were made on finely ground samples of these plant parts from samples collected from different rates of planting. These samples had been dried to a constant weight. Link and Tottingham (17) have shown that the drying of plant materials does not change their total nitrogen content. The data in table 15 show the average milligrams of nitrogen per gram of sample for samples collected in 1931 and 1932.

TABLE 15. MILLIGRAMS OF NITROGEN IN EACH GRAM OF GRAIN AND COBS.

Date	Rate of planting 1 Kernels	1 Cobs	3 Kernels	3 Cobs	5 Kernels	5 Cobs
1931						
Aug. 3	31.1	9.5	26.5	13.5	23.3	----------
Aug. 10	20.1	7.2	22.0	5.8	41.4	13.9
Aug. 17	18.3	3.6	17.3	8.0	18.4	6.5
Aug. 24	18.9	3.9	17.3	3.4	17.4	5.5
Sept. 10	16.2	2.8	16.5	2.4	14.6	3.8
Sept. 16	16.3	2.9	17.6	5.1	19.2	9.4
Sept. 26	15.6	4.2	12.6	3.8	13.3	3.1
Oct. 2	19.1	3.8	15.1	3.2	22.9	3.2
Oct. 21	17.9	2.9	15.6	4.4	11.6	3.4
1932						
July 25	19.3	----------	17.0	----------	19.5	----------
Aug. 1	17.4	----------	16.1	----------	17.3	----------
Aug. 8	25.1	10.6	18.5	7.2	21.5	13.1
Aug. 15	15.7	3.8	14.8	4.0	18.6	4.8
Aug. 22	18.2	4.9	10.6	4.3	13.0	3.5
Aug. 29	19.3	2.9	13.4	3.0	11.2	2.7
Sept. 15	13.2	4.2	14.4	2.6	11.9	3.1
Sept. 26	15.4	1.7	13.9	2.0	12.3	2.4
Oct. 13	18.5	2.9	13.2	3.8	10.7	3.6
Oct. 21	16.6	3.1	13.7	3.0	11.8	2.4

By the time the kernels could be separated from the cobs a gram of dry kernels contained about 25 to 30 milligrams of nitrogen. A few weeks later the kernels contained from 15 to 20 milligrams of nitrogen per gram, while the cob material contained only about 8 to 10 milligrams of nitrogen. By the time the ears had reached maturity the kernels contained from 10 to 15 milligrams of nitrogen per gram, and the cobs contained about 2.5 to 3 milligrams of nitrogen per gram of material.

Data presented in table 15 were analyzed for variance to determine whether rate of planting affected the nitrogen content of the kernels and cobs. Rate of planting had no significant influence upon the nitrogen content of the kernels, but did seem to have a significant influence upon the nitrogen content of the cobs. The variation in the percentage of nitrogen in the samples taken at the different dates is highly significant for both kernels and cobs.

TABLE 16. STATEMENTS ABOUT SIGNIFICANCE OF QUANTITY OF NITROGEN IN KERNEL AND COB MATERIAL COLLECTED AT WEEKLY INTERVALS FROM DIFFERENT RATES OF PLANTING.

Nitrogen samples	Between means of dates	Between means of rates
Kernels	Highly significant	Not significant
Cobs	Highly significant	Significant

The variations in the response of the plants which were planted at different rates present a very interesting problem. During the early part of the season there was practically no difference in the leaf area per plant of the plants from any rate of planting. At the same time there was very little variation in the dry weight of the plants or in diameter of the stalks. There is no indication that there was any significant difference in the rate of food making, as measured by increase in dry weight of the leaves.

By the middle of July there was a significant difference in the leaf area of plants grown at different rates. The maximum leaf area was reached at a much later date in the plants from the thinner rates. There was also a more rapid decrease in the leaf area of the plants in the thicker rates as a result of firing of the lower leaves. This variation in the leaf area was probably sufficient to account for the decreased yield of those plants which were planted at the thicker rates.

The total dry weight of both stalks and ears from the five's was not as large as that from the three's. In three seasons the five's produced a larger yield than the one's, but in the very dry year of 1930 the yield from the five's was practically the same as that from the one's. From a practical point of view the individual plants which were planted in large numbers per hill did not seem to be as economical in the utilization of the food (carbohydrates) and water which were available.

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